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ScienceDirect

Journal of Sport and Health Science 5 (2016) 70–76

www.jshs.org.cn

Original article

Athletes who train on unstable compared to stable surfaces exhibit unique postural control strategies in response to balance perturbations

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Received 2 March 2015; revised 26 October 2015; accepted 20 November 2015
Available online 11 January 2016

Abstract

Background: Athletes have been shown to exhibit better balance compared to non-athletes (NON). However, few studies have investigated how the surface on which athletes train affects the strategies adopted to maintain balance. Two distinct athlete groups who experience different types of sport-specific balance training are stable surface athletes (SSA) such as basketball players and those who train on unstable surfaces (USA) such as surfers. The purpose of this study was to investigate the effects of training surface on dynamic balance in athletes compared to NON.
Methods: Eight NON, eight SSA, and eight USA performed five 20-s trials in each of five experimental conditions including a static condition and four dynamic conditions in which the support surface translated in the anteroposterior (AP) or mediolateral (ML) planes using positive or negative feedback paradigms. Approximate entropy (ApEn) and root mean square distance (RMS) of the center of pressure (CoP) were calculated for the AP and ML directions. Four 3 × 5 (group × condition) repeated measures ANOVAs were used to determine significant effects of group and condition on variables of interest.
Results: USA exhibited smaller ApEn values than SSA in the AP signals while no significant differences were observed in the ML CoP signals. Generally, the negative feedback conditions were associated with significantly greater RMS values than the positive feedback conditions.
Conclusion: USA exhibit unique postural strategies compared to SSA. These unique strategies seemingly exhibit a direction-specific attribute and may be associated with divergent motor control strategies.

Keywords: Athletes; Balance; Negative feedback; Postural stability; Training

1. Introduction

Postural sway is the continuous movement of one's center of mass (COM) about the base of support in order to maintain an upright stance.[1] In an erect posture, humans are in a continuous state of adjustment and must counter the effects of gravity through alterations in tonic muscular control.[2] The central nervous system utilizes information from the sensory (visual, vestibular, and somatosensory) and motor systems to make adjustments in muscle activation to control upright stance through an efficient pairing of feedback and feedforward mechanisms.[1,3,4] From a motor control perspective, postural sway can be viewed as a measure of the effectiveness of sensorimotor integration in response to changing COM locations relative to the base of support.[5]

It has been suggested that optimal postural control is associated with minimal magnitudes of postural sway about a central point of equilibrium.[6] Thus, greater magnitudes of sway are interpreted as an inability to produce optimal control of posture and may be associated with an unhealthy state or general decline in sensorimotor performance such as with advancing age.[7,8] It is theorized that a more refined or healthy postural control system will exhibit smaller postural sway magnitudes during a given task compared to a less refined or pathological system. These postulations are supported by existing literature that has demonstrated that elite athletes exhibit smaller sway magnitudes when compared to either non-elite

Peer review under responsibility of Shanghai University of Sport.
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http://dx.doi.org/10.1016/j.jshs.2016.01.010
2095-2546/

athletes or non-athletes (NON).[9] In addition, healthy young adults demonstrate less sway magnitude when compared to older adults (65+ years) during eyes open, quiet stance, and a dynamic obstacle avoidance condition. These data suggest that the total sway magnitude is indicative of the status of the postural control system within a given individual. However, this suggestion is based upon the assumption that the magnitude of sway is indicative of precision within the system during a bilateral standing task.

During athletic participation, motor performance is goal-oriented and dependent upon the mechanical demands of the sport, training status, and training paradigm. Multiple studies have demonstrated that certain athletes (volleyball players, canoers, kayakers, and ice skaters) all demonstrate greater sway magnitude in eyes open conditions when compared to healthy NON.[10–12] During eyes closed and unstable platform conditions (foam board) these same athletes were not significantly different from healthy NON. As such, greater sway magnitude is not always an indicator of the health of the postural control system or reduced balance. This could be explained by the dynamical systems theory where biological systems self-organize in order to adapt to the environment, biomechanical and morphological constraints of the tasks.[5] All of these athletes participate and train in visually stimulating rapidly changing environmental conditions that involve moving suddenly from a static position (i.e., ready stance prior to a volleyball serve; calm slow water paddling transitioning to rough rapids or a sprint; smooth single plane motion skating to a jump, spin or turn). As a result, this greater sway magnitude could be a trained motor strategy that enables these athletes to fluidly switch from static positions to more unstable positions. These results could point to training adaptations, such as a unique training paradigm(s) that are adopted within the postural control system for certain athletes for specific motor performance training goals. Thus, caution is suggested when interpreting greater sway magnitude results in certain athletic populations.

Training status (trained *vs.* untrained) significantly affects postural stability across the lifespan.[9] In fact, most studies have focused solely on athletes who train and compete on a stable surface such as a floor or a ground. However, not all athletes compete on these stable surfaces. With the popularization of extreme sports such as surfing and snowboarding, an increasing number of athletes who participate in sports compete on unstable surfaces. Emerging evidence[10] has suggested that these athletes may adopt unique neuromuscular and biomechanical strategies to maintain upright stance (static stance). These unique postural control strategies are proposed to be a function of the characteristics of the support surface on which stable surface athletes (SSA) are compared to unstable surface athletes (USA) who train. We suggest that SSA apply force to their support surface, and in response their COM is translated in the opposing direction to that of force application. Conversely, USA apply force to their support surface, and in response the support surface moves in the direction of force application. The strategy adopted by USA during athletic performance (surfing or snowboarding) has been suggested to be dominated by a feedforward control strategy which manifests in a proximal to distal control strategy in response to balance perturbations. This is in contrast to the SSA which may initiate movement at the level of the foot and ankle.[10] Continued examination of these unique control strategies in dynamic environments will further elucidate these proposed mechanisms.

While few research studies have focused on the effects of training paradigm on postural control strategies in these functionally different groups, most studies pertaining to postural stability have utilized traditional measures of postural stability such as sway magnitudes or sway excursions. In contrast to traditional measures of postural stability, non-linear measures provide a quantitative assessment of the moment-to-moment variability within a time-series. An emerging body of literature has suggested that non-linear measures of postural stability may offer unique insight into the stability of the neuromuscular system and the efficacy of the postural control strategy.[1–3,5–9] Specifically, it has been shown that non-linear measures of variability such as approximate entropy (ApEn) are capable of detecting subtle differences in the characteristics of the center of pressure (CoP) profile even in the absence of significant differences in traditional measures of sway including CoP excursions, resultant distance or path length, and sway accelerations.[5,9,13,14] Measurement of both the quantity and quality of postural sway is likely to offer a more complete description of the health and performance of the underlying sensorimotor system.

At present, few research studies have focused on the effects of training paradigm on postural control strategies in these two functionally different groups. However, the unique training and postural control strategies may provide a platform from which evidence-based therapeutic interventions may be developed to improve balance in a variety of populations. Therefore the purpose of this study was to investigate the effect of different feedback training paradigms on traditional and non-linear measures of postural stability when balance is perturbed by a translating force platform. Supported by existing literature, it is hypothesized that USA will exhibit significantly greater measures of variability compared to SSA.

2. Methods

2.1. Subjects

Twenty-four healthy adults aged 18–30 years were recruited to participate in the current study. Participants were recruited based on the balance paradigm in which each athletic participant participated including: NON (age: 22.9 ± 2.5 years), SSA (age: 22.6 ± 3.2 years), and USA (age: 23.1 ± 2.5 years). NON participants were characterized as being sedentary or participating less than 30 min of recreational physical activity fewer than 3 days per week.[15] SSA participants were recreationally active in a traditional sport at least 30 min per day for 3 or more days per week on a stable surface. The subjects were primarily composed of graduate students who participated in intramural sports 4–5 days per week. Each of these games or practices lasted no less than 1 h. While no measures of physical fitness were measured, all participants were familiar with and capable of their sports. A stable surface was characterized by a surface